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Critical Factors Affecting Successful Technology Transfer

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CRITICAL FACTORS AFFECTING SUCCESSFUL TECHNOLOGY TRANSFER

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ABSTRACT

In 1987, Virginia established a technology transfer program through a partnership between Virginia's Center for Innovative Technology and the Virginia Community College System. This program was designed to help small and medium sized firms improve their profits through the utilization of technology.

The foundation of the program is the outreach role played by the Technology Transfer Directors. The Directors are characterized as brokers, change agents, or intermediaries. As such, they are positioned between the source of a technology or body of knowledge and the potential user. This role is an important one. The Director must be able to serve as an intermediary between very different organizations and people.

The study shows that the brokers have the most impact on their clients when they deal with firms that have more than 11 employees and are technical or semi-technical in nature. The most critical activities in which brokers engage are providing technical information, suggesting alternative approaches to problems, technology implementation, technology modification, and market identification. When brokers engage in these activities, they have significant impact on increasing business, retaining business, improving productivity, and strengthening the firms' competitive position and technical capacity.

CRITICAL FACTORS AFFECTING SUCCESSFUL TECHNOLOGY TRANSFER

CHAPTER I

STATEMENT OF THE RESEARCH PROBLEM

As the world becomes smaller, the relationships between various societies and cultures become closer and more complex. Historically, the United States found itself to be unique among industrialist nations. It was entrepreneurial in nature and thrived on the development of new technology and innovation for economic advantage. However, other countries, such as Japan and the European community, particularly Germany, are now competing in the markets that we once considered to be ours alone. Other countries are making significant inroads in such industries as electronics, automobile manufacturing, machine tools, and machinery. In addition, with the advent of electronic communications, more efficient travel modes, and a host of economic factors, we now do, in fact, compete in a world market. And we find ourselves, in some instances, not in a leadership position.

More and more literature that addresses the issue of U.S. competitiveness is making reference to the inefficient way that we move technology from the laboratory into commercial application. The literature suggests that the process in our society is slow and inefficient compared to cultures like Japan. According to Robert S. Cutler, the differences between our technology transfer practices and those of Japan stem largely from cultural and institutional factors (Cutler, 1988).

The United States is, perhaps, unique in the way that it develops new technology. Unlike many societies, there are many loci of research and development in our society. The primary locations for research are universities, private companies, and the federal government. In the federal research arena, one can find research being done in several ways: in government owned and operated laboratories, government owned but company operated facilities, and at universities. There is no centrally defined research agenda. In addition, the developers of technology and the end users of the technology are not necessarily the same. This is different than many of the competitors of the United States. In many of those countries, the developers and users are the same.

Recently, the United States has begun to explore ways to improve the diffusion of technology from the laboratories to the marketplace. Increasingly, we find states that are establishing mechanisms to promote the utilization of technology. For example, Pennsylvania has the Pennsylvania Technical Assistance Program (Penntap) at Penn State University; Michigan has established the Southeast Michigan Technical Assistance Program (SEMTAP), based at the University of Michigan; and Ohio has the Ohio Technology Transfer Organization (OTTO), based in the Ohio Department of Development and the community/technical colleges. All of these programs attempt to work with businesses in order to assist them in utilizing new or appropriate technologies.

In 1987, the Commonwealth of Virginia initiated its own program, designed to help small and medium sized businesses improve their profits through the utilization of technology. The program was developed as a partnership between the Virginia Community College System (VCCS) and the Virginia Center for Innovative Technology (CIT). The Economic and Technology Development Program (E&TD) borrows from many of the other programs around the country, utilizing the strong points of each.

The foundation of the program is the outreach role played by a Director of Economic & Technology Development, located at each of 10 community colleges. In total there are 10 Directors, specifically trained in technology transfer techniques. The Directors work with area businesses, assessing their needs that have a potential solution in the application of technology. The Director is a technology broker or facilitator.

The role the Director plays in the technology transfer process is an important one. The Director must be able to serve as an intermediary between very different organizations and people. In the case of a non-technical company that desires to apply a technology to its operation, the possessor of the technology and the user have very different orientations. The broker must build a bridge of understanding between them, and facilitate the successful movement of the technology.

The profession of technology transfer is growing and becoming more important in terms of maintaining American competitiveness. The study of technology transfer, or the diffusion of innovation, has addressed the circumstances under which a change agent (technology broker) is likely to be most successful. This thesis will use new variables that will further define the market in which such programs will be most successful.

CHAPTER II

THEORETICAL FRAMEWORK

This project is designed to bring clarity to the circumstances under which a technology broker is most efficient. A review of the literature is necessary to determine if there is a theoretical basis upon which to structure the investigation. The bodies of literature that will likely contain the information that is relevant to this research project are fairly specific. They include the topics of diffusion of innovation, technology transfer, technology brokering, transfer of innovation, networking, and complex organizations.

A review of this literature revealed much work on the diffusion of innovations. The following discussion is a brief review of the pertinent issues raised in that literature. It serves to put this thesis in perspective.

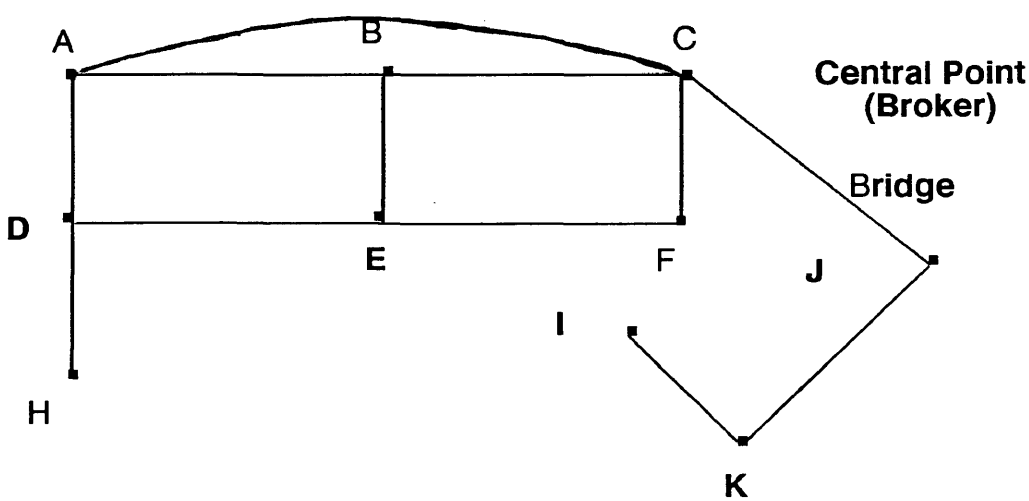
One of the core concepts in this proposal is technology transfer. It is important to define technology and technology transfer. According to Robert A. Solo, technology is "the organized capability of a social group to perform some purposeful activity"

(Solo, 1972). According to Everett Rogers, "technology transfer is the process in which an innovation originating in one institution or system is adapted for use in another institution or system" (Rogers, 1962). In the transfer process both the transferor and the recipient of the technology must creatively participate. By these definitions there are many kinds of technologies. However, for the purposes of this thesis proposal, the focus is on the production of goods and services that have potential market value, that is, economic technologies (Solo, 1972, P.5).

The Economic & Technology Development Directors are characterized as brokers, change agents, or intermediaries. As such, they are located between the source of a technology or body of knowledge and the potential user. The role of the broker is to link persons having complementary interests, transferring information or resources, and otherwise facilitating the interests of persons not directly connected to one another (Aldrich and Von Glinow, 1990). Essentially, the broker is the pivot point in a network. The broker creates bridges that link two regions of a network that would otherwise have little, if any, contact with each other. In Figure 1, there is a bridge between A and J which links two otherwise isolated sections of the network (Aldrich and Von Glinow, 1990). A central role

FIGURE 1

Social Network: Centrality, Bridges, and Brokers



Source: "Small World, Isn't It? Personal Networks and Infrastructural Development". Howard E. Aldrich and Mary Ann von Glinow.

of a broker is to facilitate the bridging of these gaps in a network, thus making more resources available to the client. In other words, the broker serves as a link which expands the entrepreneurs' reach beyond their immediate social circle (Aldrich, Dubini, Reese, 1990).

In a study done of Yunen Island, Mexico, Gibson and Rossi looked at the role of the broker in the community and economic development process. They defined a triadic relationship between the community (receiver), worker (broker), and the government agencies (possessors of resources). They found that there were three important points to the task of the broker: 1) facilitating informational flow to and from the agency, as well as their reciprocal inputs into one another; 2) cultural or class reconciliation between the agencies and communities, and their mutual perceptions of one another; 3) need to assist the community to adapt to its new situation, once a development process has been instrumentalized (Gibson and Rossi, 1979). This illustrates and reinforces the significance of the role of the broker in networking, and adds the dimension of helping to operationalize the ideas that the broker brings to the client.

Perhaps the most appropriate program to compare the technology transfer program to, and thus the role of the technology broker, is the cooperative extension service. That activity, located in land grant universities, has extension agents who work with farmers to utilize new techniques, products, etc., for the purpose of improving their farming operations. In a project conducted by Everett Rogers and Harold Capener, the characteristics of farmers who have a high and a low degree of contact with their extension agents were studied. The major findings of the study are summarized as follows (Capener and Rogers, 1960):

1. Farmers perceive the county extension agent as their most important single line of communication with agricultural scientists.

2. Farm operators who made greater use of their county extension agent were characterized by: more education, a higher social class position, larger farms, higher farm incomes, employment in off-farm work, both owning and renting farm land, readership of more farm magazines, better acquaintance with the extension agent, and a better understanding of the extension service.

3. No significant relationships were found between extension contact scores and age, venturesomeness toward new ideas, belief in agricultural magic, distance from county seat, size of farm (acres), and length of the adoption period.

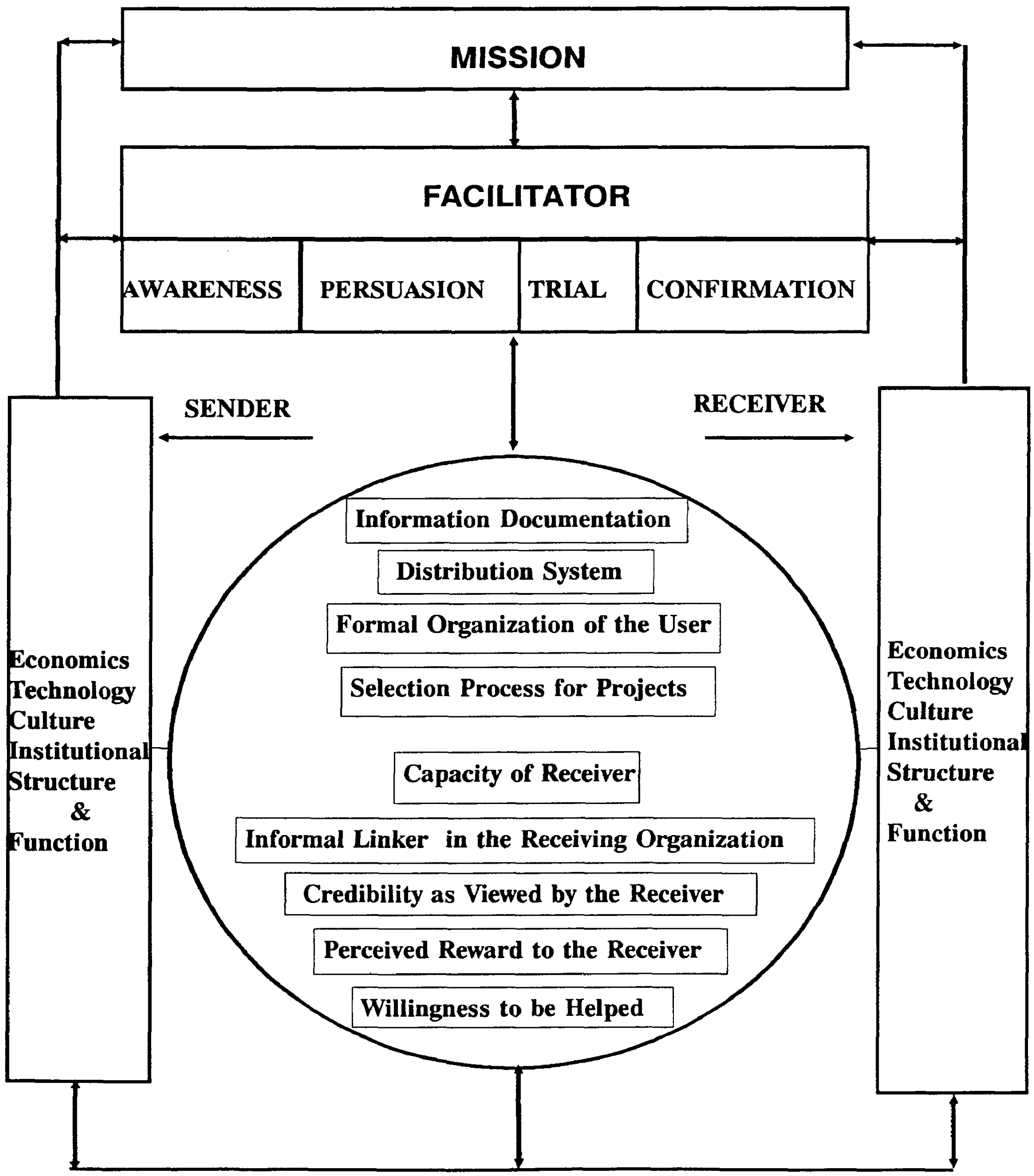
4. Farmers who were visited personally by the county extension agent made greater use of other types of extension contact.

Just as the extension agent is important to the diffusion of innovation among farmers, the technology broker is important to the movement of technology to business and industry. Five stages have been identified in the process of adopting a new technology: awareness, interest, evaluation, trial, and adoption (Rogers, 1963). While these stages were applied by Rogers to the agricultural community, they also apply to business and industry. In a model for technology transfer proposed by Dr. Robert Bailey, four of the five stages in Roger's approach are used. They are: awareness, persuasion (interest), trial, and confirmation (adoption). This model is illustrated in Figure 2 (Bailey, 1990). Bailey's model also includes many of Roger's criteria for successful diffusion of innovations. These appear in the circle on the model. They deal with characteristics of the receiver as well as the facilitator or broker.

The role that a technology broker plays in the innovation and technology transfer process is a varied one. He must be an intermediary between very different organizations and people. In general, large companies that are active in research themselves call for a more passive approach by the broker because they have people with the interest and ability to search the literature and who are already knowledgeable. On the other hand, companies with little or no research-oriented staff, regardless of size, require a more aggressive approach by the broker (Walton, 1987).

Implicit in the diffusion process is a difference

FIGURE 2



THE TECHNOLOGY TRANSFER PROCESS

Source: "The Development of a Practical, Planning Framework for International Technology Transfer. Robert E. Bailey.

in levels of knowledge, expertise, background, and education between the possessors of the information or technology and the receivers of it. It is the critical role of the broker to bridge that gap. Dr. Everett Rogers presents a study of the technology transfer process in less developed countries (Rogers, 1972). In this work, he views technology transfer as a method to improve the economic development of that country. Rogers is particularly interested in the diffusion of technology from more developed to less developed countries.

Rogers' study revealed that communication was critical to the transfer of technology. He found that in the transfer of technology from more developed to less developed countries, problems of heterophily existed. (Rogers defines heterophily as the degree to which individuals are different in certain attributes). A more favorable situation for effective communication occurs when the people who are communicating are homophilous, that is they have certain similar attributes. One of the most distinctive problems that characterizes the communication of innovations in the process of economic development is that the source is usually quite heterophilous to the receiver (Rogers, 1972, p. 92).

Rogers relates this problem to a model developed by McAnany and Linwood (1957) that shows the cross national communication of research outputs from more developed countries to less developed countries. The following paradigm was developed:

MORE DEVELOPED NATION	LESS DEVELOPED NATION
Basic Research	Basic Research
Applied Research	Applied Research
Practice	Practice

The solid lines show movement of information and technology between individuals with similar attributes (homophily), with very little resistance. However, the dotted lines represent the translation of research into application. There is a high degree of heterophily in communication.

The research utilization process, according to Rogers, is a model that can help reduce the consequences of heterophily. There are three social systems involved in this process:

1. Research System
2. Change Agent System
3. Client System

The Research System produces results or innovations. The Change Agent System translates client needs to researchers and transfers innovations to clients. The Client System recognizes needs for research and therefore leads to its initiation, and later adopts the innovations that result from the research (Rogers, 1972, p. 95). The following paradigm, taken from the book Inducing Technological Change for Economic Growth and Development, by Robert Solo and Everett Rogers, illustrates the research utilization process:

RESEARCH SYSTEM
Function: Create and develop innovations

↑ #2 Needs | #3 Innovations ↓ | ↑ #6 Feedback

CHANGE AGENT SYSTEM
Function: Translate client needs to researchers, and diffuse innovations to clients

↑ #1 Needs* | #4 Innovations ↓ | ↑ #5 Feedback

CLIENT SYSTEM
Function: Recognize need for research, and adopt innovations

* The communication flows numbered in this paradigm are:

#1 Flow of client needs (for information) to change agents.

#2 After interpretation and clarification, these needs are transferred to the research system.

#3 Researchers attempt to provide needed information for clients' needs, either from accumulated knowledge or via newly-originated research.

#4 Change agents distill and interpret this new information (innovations) for clients.

#5 Feedback from clients to change agents on the adequacy of the new information in meeting their needs.

#6 Change agents convey clients' feedback to researchers, perhaps leading to further client needs and recycling of the entire process.

Rogers and Bhowmik propose a series of propositions that characterize the homophily-heterophily concepts. These propositions are presented as "sensitizing concepts" in that the exact dimensions of homophily-heterophily would vary with different communication situations (Bhowmik and Rogers, 1970-71, pp. 528-538):

Proposition I: Communication patterns frequently tend to be homophilous.

Proposition II: More effective communication occurs when source and receiver are homophilous.

Proposition III: Effective communication between source and receiver leads to greater homophily in knowledge, beliefs, and overt behavior.

Proposition IV: For maximum communication effectiveness, a source and a receiver should be homophilous on some variables relevant to the situation.

Proposition V: Heterophilous communication is more effective when source and/or receiver are status inconsistents.

Proposition VI: A heterophilous channel/source is perceived by a receiver as having qualification credibility, while a homophilous channel/source is perceived as having safety credibility.

Proposition VII: Heterophilous communication is more effective when the source has a high degree of empathy with the receiver.

Proposition VIII: Heterophilous communication is more effective when the source has greater empathy than the receiver.

Proposition IX: Heterophilous communication is more effective when the source attends to feedback from his receivers.

Proposition X: Source-receiver homophily is positively related to interpersonal attraction, and both are related to more effective communication.

Proposition XI: More traditional systems are characterized by a greater degree of homophily in interpersonal communication.

While all of these propositions are not directly related to this research, they are illustrative of the importance of the various elements of communication in the effective brokerage of technology. The critical role of the broker is to interact with the sender and receiver of information, and create circumstances under which the flow of information can occur. Specifically, Propositions V, VI, VII, VIII, X, and XI are not as directly related to the research as are the others.

A change agent must recognize the differences between the source and the receiver. Often a social chasm exists between the system (source) and the client system (receiver). Typical disparities include subcultural language differences, socioeconomic status, technical competence, beliefs and attitudes. For a change agent to be successful in his role of facilitating change with the client, he takes on several roles (Rogers and Shoemaker, 1971, pp. 228-30):

1. develops a need for change
2. establishes a change relationship with the client
3. diagnosis the problem
4. creates intent to change in client
5. translates intent into action
6. stabilizes change and prevents discontinuances
7. achieves a terminal relationship with client

In fulfilling these roles, the change agent functions as a communication link between two social systems (Rogers, 1962, p. 257), as illustrated in Figure 3. Research suggests that there are several generalizations that can be made about the factors that affect the success of the change agent. Success is defined as the amount of innovations that are adopted by the clients. These generalizations are (Rogers and Shoemaker, 1971, pp.233-247):

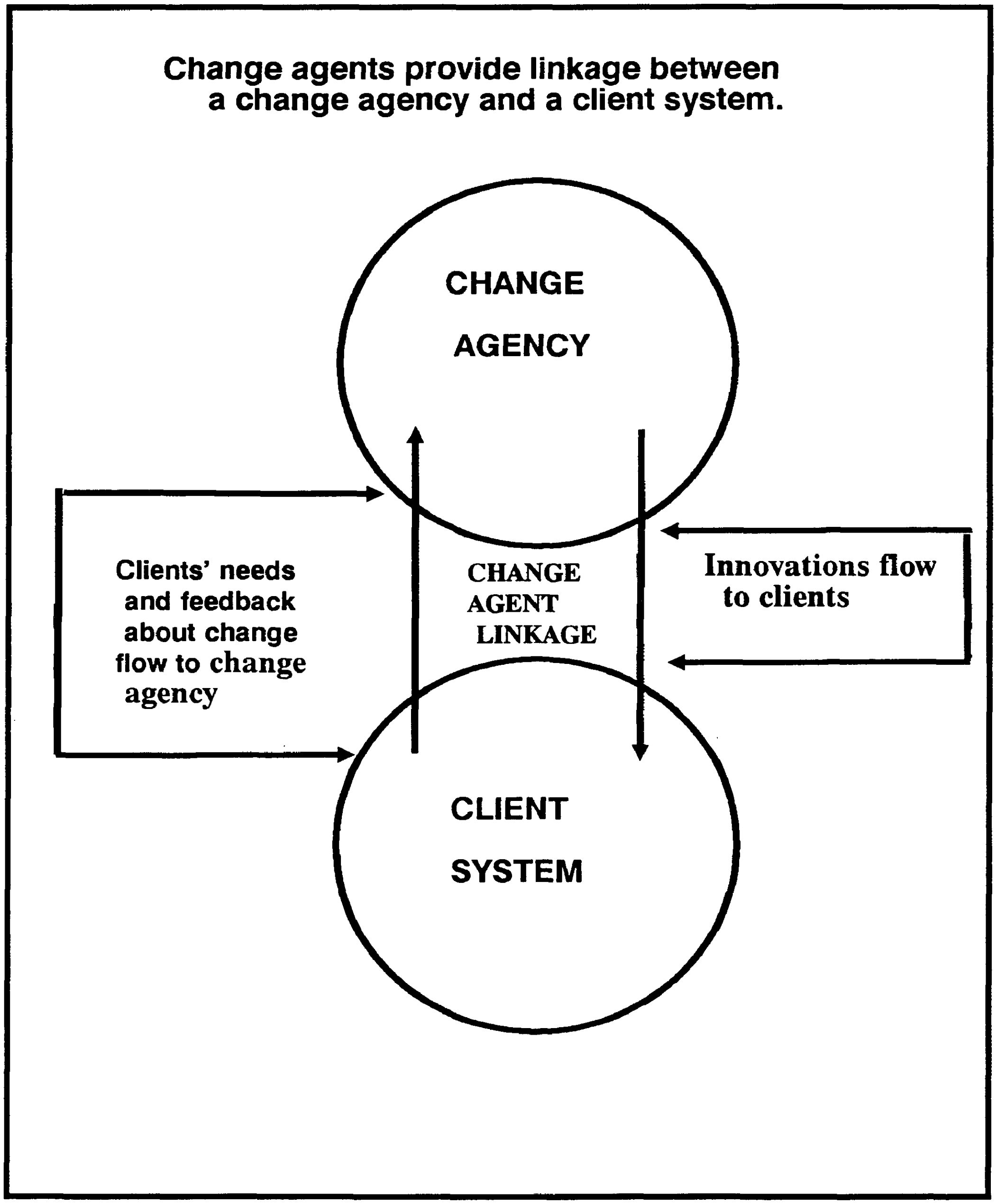
1. Success is positively related to the amount of effort the agent puts into the change.

2. Success is positively related to client orientation rather than change agency orientation.

3. Success is positively related to the degree to which the program is compatible with the client's needs.

4. Success is positively related to the change agent's empathy with the client.

FIGURE 3



Source: Communication of Innovations.
Everett M. Rogers, F. Floyd Shoemaker.

5. Success is positively related to his homophily with the client.

6. Success is positively related to the extent to which the change agent works through opinion leaders.

7. Success is positively related to the change agent's credibility in the eyes of the client.

8. Success is positively related to the change agent's efforts in increasing the client's ability to evaluate innovations.

Items 4, 6, and 7 will not be dealt with in this thesis.

It is not the purpose of this thesis to prove or disprove the work that has been cited as the theoretical base for this research. With the introduction of new variables, taken with the information and knowledge already established, it is intended to more closely and accurately define the circumstances under which the technology broker is of most value to the client.

CHAPTER III

THE RESEARCH QUESTION

The central question to be addressed in this thesis is "when is the technology broker of most value to the client firm?". Based upon the theory already developed, as well as this author's 15 years experience in the technology transfer field, there are many variables that will affect the value of the broker. The primary variables that will be examined in this thesis are firm type (technical, semi-technical, and non-technical), firm size (number of employees), and level of impact of broker (major, minor, no).

These variables are not the only ones that affect the value of the broker. Other relationships will be examined based upon the frequency distribution of the other variables for which data are collected. Such variables as the college identification number, project duration, sources of assistance provided, and areas of service may be analyzed. While there will be an emphasis on the analysis of the primary variables mentioned above, others will be considered if it appears that they have major significance.

The expectation is that as the size of the company and its level of technology increases, the value of the technology broker decreases. Companies that are not technologically oriented and are small in size will have a heterophilous relationship (one that is characterized by differences in certain characteristics or levels of knowledge) with the possessors of technology that can help them. Therefore, for the latter, the technology broker becomes critical in bridging the gap in order to facilitate the diffusion process.

The major concepts in this study that must be clarified are company size, level of technology, effective use of the technology broker, technology transfer, and level of impact of the technology broker. Each of these concepts must be defined in specific terms so they can be measured. The following are the proposed definitions:

COMPANY SIZE:	Determined by number of employees. Three categories will be used (1-10, 11-20, 21+)
EFFECTIVE USE OF BROKER:	Indicated by the following: increased business volume, retention of existing business, production cost savings, manpower savings, time saved, stronger competitive position, stronger managerial capacity, and stronger technical capacity. (Defined by client)

TECHNOLOGY TRANSFER:	The process in which an innovation originating in one institution or system is adapted for use in another institution or system (Rogers, 1972).
LEVEL OF IMPACT OF BROKER:	Indicated by distribution in three categories: major impact, minor impact, no impact. (Defined by client).

CHAPTER IV

RESEARCH DESIGN

The universe of this study is Virginia's Economic and Technology Development program. Data was collected using the Directors' Case Record form (Appendix B). These forms are located at the offices of the Center for Innovative Technology in Herndon, VA. The author recorded the data according to the Code Book (Appendix C). More data was collected than will be used in this thesis. It is the intent of the author to make the data available to future graduate students for consideration in the development of other master's theses. In addition, the author anticipates doing further research using some of the data.

The period of time for which data was used is from September, 1987, to June, 1990. All of the cases for which data are being used are closed. That is, technology services were delivered (98%), the project was a non-problem (1%), or the problem could not be solved (1%). (A total of 216 cases make up the data set). The types of firms in the study are categorized as Technical, Semi-Technical, and Non-Technical. The size of the firms are categorized as Small (1-10 employees), Medium (11-20 employees), and Large (21 or more employees). The following table shows the number of business types by size:

FIRM TYPE

		Technical	Semi Technical	Non Technical	
FIRM	Small	12	34	26	72
	Medium	1	13	7	21
SIZE	Large	19	89	15	123
	Total	32	136	48	216

The age of the firms that are studied are as follows:

1 year or less	41
greater than 1 year but not greater than 5 years	67
greater than 5 years	108

The independent variables of the study will be firm size, the level of technological sophistication of the firm (business type), and critical brokering activities. It should be noted that the data are not a probability sample, but a saturation, non-probability sample (Babbie, 1986).

All the data used in the study are reported to the Center for Innovative Technology by the field Directors. In general, the information that will be used is provided by the clients themselves, to the

Directors, who then make the final reports. Data collected in this way are more valid and reliable than if the Director made estimates of the value of the technology services provided.

There have been several approaches to classify firm types. The literature contains two approaches that are particularly applicable to this study. One approach to understanding organizational diversity is based on the outputs of the firm, that is its products or services. The U.S. Office of Management and Budget developed the Standard Industrial Classification (SIC) based on the outputs of the firms (Aldrich and Marsden, 1988). The other approach is based on activity systems within the firm. Joan Woodward (1965) was one of the first researchers to systematically document structural diversity based on activity systems. She classified her sample of manufacturers by the complexity of their technical processes (Aldrich and Marsden, 1988).

The data set for this study included the SIC code as well as a written description of the primary activity of the firms. Applying the concepts of Woodward (complexity of technical processes) and the SIC code, the author categorized the firms as technical, semi-technical, and non-technical. The following descriptions illustrate each classification. A technical company is one that has as its product computer chips. The equipment used to manufacture the chips is automated, utilizing robotics and sophisticated electronic and pneumatic systems. Also considered technical would be a machine shop that uses numerical control systems on the equipment. The technical processes are not as complex as the first example, but is still technical.

An example of a semi-technical company is one that repairs and rebuilds machinery. The work requires a fair degree of technical expertise, but not at the level of the technical company.

A non-technical company is one that does not utilize technology to any significant degree. A law office, department store, accountant services, standard warehouse operations, etc., are all examples of non-technical businesses.

Another concept that must be discussed is that of what constitutes the EFFECTIVE use of a technology broker. Again, the measures used will be those defined by Virginia's Economic and Technology Development program. The following chart shows the factors of effectiveness and how they are measured:

MEASURE OF IMPACT

BUSINESS OUTCOME	Major Impact	Minor Impact	No Impact
Increased business volume			
Retention of existing business			
Production cost savings			
Manpower savings			
Time saved in new product introduction			
Stronger competitive position			
Stronger managerial capacity			
Stronger technical capacity			

In addition, data will be available on the economic value of some completed technology transfer projects.

Any research must be as specific and well defined as possible. In this proposal, the boundaries are very clear (Dubin, 1978). The research will be conducted using data generated from clients of the Economic and Technology Development program. The sample will consist of those firms which requested assistance in solving a problem. Information will come from the ten sites across Virginia.

In addition to the analysis to be done comparing firm size and business type, analysis will also be run to describe the relationship between business type and level of impact of the assistance provided by the technology broker. The format for analysis is as follows:

LEVEL OF IMPACT OF A TECHNOLOGY BROKER
ACCORDING TO COMPANY TYPE

		COMPANY TYPE		
		Technical	Semi-Technical	Non-Technical
LEVEL	Major Impact			
OF	Minor Impact			
IMPACT	No Impact			

This analysis will describe how important the technology broker is to each of the three company types. It is anticipated that there will be more cases of major impact in the non-technical cell than in the others.

Another analysis to be done will describe the relationship between company size and level of impact. This analysis is important because it will quantify the effectiveness of the technology transfer broker in terms of another set of variables.

LEVEL OF IMPACT OF A TECHNOLOGY BROKER
ACCORDING TO NUMBER OF EMPLOYEES
IN A FIRM

		LEVEL OF IMPACT		
		MAJOR IMPACT	MINOR IMPACT	NO IMPACT
NUMBER	1-10			
OF	11-20			
EMPLOYEES	21+			

Again, it is expected that companies with 1 -10 employees will say that the impact of the services rendered by the technology broker was major. Conversely, we would expect that the companies with more than 21 employees will show either minor or no impact from the use of the technology broker.

It is the intent of this thesis to empirically define the size and level of technology of companies that would benefit most from an organized technology transfer program. This information is critical to those jurisdictions which are contemplating the establishment of such activities, as well as those which are already operating such programs. In addition, it is anticipated that a study of the additional data collected will reveal other important relationships that enhance the technology transfer process. These relationships will also be highlighted.

CHAPTER IV

FINDINGS

It was anticipated, based on the research of the literature, that certain relationships between firm size, level of technology, and impact of the broker, would exist. Those results will be discussed in this chapter. However, the bulk of the discussion will focus on the emergent issues that were revealed as a result of the research.

Anticipated Results

As discussed in the previous Chapter, the literature suggested that one could expect to find the technology broker would have the greatest level of impact on the smaller, less technical firms. One would expect that when information is moving from a technical source to a non-technical receiver, the broker would play a very important role.

The actual results, however, did not meet these expectations. As Table 1 (page 60) shows, the only business outcomes that are significantly impacted by firm size and type of business are production cost savings, retention of business, and a stronger managerial capacity. These are statistically related, but not strongly. The only strongly related relationship is that of firm size to manpower savings (tau=.266, sig. level=.0002). And the only outcome that is significantly impacted by <u>both</u> firm size and business type is stronger managerial capacity, and those relationships are not very strong.

The theoretical base for the expected outcomes is rooted in the agricultural extension service and in international technology transfer. It is possible that those principles do not hold true in a domestic business environment. Further, in order to utilize the technology solutions and opportunities presented by the brokers, a reasonable amount of capital is required. Larger firms have a greater opportunity to access capital for those purposes. They may, as a group, be in a stronger financial position than the smaller firms.

Firms with a higher level of technology in the organization are already aware of the economic benefits that the application of the appropriate technology can generate. They, therefore, are more likely to use a technology that is presented to them.

Firms that use technology in their business or depend upon it for the core of their products, operate in a highly competitive environment. They are aware of the market advantage that technology can provide, and are likely to be receptive to its introduction. As Bailey's model suggests, one of the characteristics of the receiver of technology is a willingness to be helped. Without this, the receiver will not be receptive to the information be provided, and will not be likely to use it. In the case of the firms that know about technology, they are receptive and are willing to be helped by the brokers.

These scenarios, singly or together, could explain why, in this study, the larger, more technical firms, were more highly impacted by the activities of the technology brokers.

Emergent Findings

Even though the data did not support the anticipated findings, the data did reveal, perhaps, even more significant information about the technology brokering (or transfer) process. Part of the data set includes a series of factors that reflect what the brokers do to provide assistance to their clients. These are referred to as the "critical brokering activities". The following list shows the frequency distribution of the percentage of times that the brokers provided each kind of assistance:

Provide technical information	65%
Suggest alternative approaches	27%
Problem identification	23%
Market identification	23%

Technology acquisition	23%
Product design	22%
Technology modification	14%
Technology implementation	13%
Meet government regulations	10%
Workforce development	8%
Capital formation	5%
International trade	5%
Financial management	3%

This distribution shows that the activities in which the brokers were engaged most often were related to technology. (The percentages exceed 100% because of multiple responses). Table 2 (page 61) shows the strength of the relationships between critical brokering activities and the measures of impact. This table shows that a number of the activities of the brokers had significant impact on the business outcomes observed. The chi square probability level and Kendall's tau coefficient suggest that problem identification, providing technical information, technology implementation, product design, suggesting alternative approaches to problem solving, technology acquisition, and technology modification all had very strong impact on business outcomes. These observations demonstrate that the activities of the brokers are consistent with the mission of the Virginia technology transfer program. Additionally, they provide a basis for additional analysis that shows which activities have the most impact on the firms served. These additional findings reflect which areas of business outcomes that the technology broker has significant impact. They can be organized in several broad categories: technology related areas, productivity, competitive position, technical capacity and management.

Technology Related Areas

One of the first observations made from the frequency distribution is that a majority of the activities involving brokers are related to technology. The highest percentage of activities is providing technical information (65%). Other technology related activities that brokers spent much of their time doing include problem identification (23%), technology implementation (13%), product design (22%), suggesting alternative approaches to problems (27%), technology acquisition (23%), and technology modification (14%). This represents 7 of 13, or 54% of the activities observed.

The frequency distribution also shows the business types that comprise the data set:

Technical	15%
Semi Technical	63%
Non Technical	22%

Seventy-eight percent (78%) of the firms served are either technical or semi technical. The frequency distribution also indicates why cases were closed. Ninety-eight percent (98%) of the closed cases for this study were closed because "technology services were delivered".

Since over 3/4 of the cases in this study are from technical or semi technical companies, it would follow that some proportion of the significant impact on the business outcomes would be for those technical or semi technical companies. The frequency distribution indicates whether the activities of the broker had major, minor, or no impact (by percent) for the recorded business outcomes. The following summary of that distribution indicates the sum of the percentages of major and minor impact:

Stronger competitive position	63%
Increase in business	60%
Stronger technical capacity	51%
Retention of business	42%
Production cost savings	41%
Time saved	41%
Stronger management capacity	30%
Manpower savings	26%

Table 1 (page 60) indicates that the type of business is strongly related to the measures of impact in three instances: increase in business, stronger management capacity, and stronger technical capacity. The strength of relationship is greatest with the stronger management capacity.

Contingency tables served as the basis for these statistics. When business type was compared to increase in business, 19 of 31 (61%) technical firms reported major impact as a result of the technology broker's activities. Sixty-three of 135 (47%) of semi-technical firms reported major impact, and 21 of 48 (44%) of the non-technical firms said there was major impact. Business type was cross tabulated with management capacity. In that relationship, 2 of 30 (7%) technical firms reported major impact, while 22 of 135 (16%) of the semi-technical firms reported major impact, and 16 of 48 (33%) of the non-technical firms reported major impact. The contingency table comparing business type to stronger technical capacity shows that 15 of 30 (50%) of the technical firms had major impact, 44 of 135 (33%) semi-technical firms had major impact, and 14 of 48 (29%) of the non-technical firms had major impact. These data suggest that the major impact for technical and semi-technical firms was in the business outcomes: increased business, stronger management capacity, and stronger technical capacity.

Table 3 (page 62) shows the strength of the impact among the measures of impact for business outcomes. Clearly there are very significant relationships shown on this table. However, there are several that are related to technology. When brokers engage in activity that increases business and retains business, there is a significant incremental impact on the strength of the firm's technical capacity.

It is clear from the data that the technology brokers do have a significant impact on various aspects of technology related issues among its clients. This is supported by the distribution of activities in which the broker engages, the distribution of the business types in the data set, the reasons why a case is closed, and by the analysis of the measures of impact of the applicable business outcomes. The data suggest that activities of the broker have the most impact on technical and semi-technical firms, with significantly less impact on non-technical firms.

Productivity

In the data set, three variables lend themselves to be clustered as measures of productivity. These variables are production cost savings, manpower savings, and time saved. These variables are among those recorded as measures of impact of business outcomes. When viewed together, these variables suggest that the technology transfer activity also has significant impact on the productivity of the firms served.

The frequency distribution for each of these variables is a sum of the percentages for major and minor impact as follows:

Production cost savings	41%
Time saved	41%
Manpower savings	26%

This distribution suggests that a significant number of cases were impacted positively by the brokers. The implication is that the brokers had a positive impact on the productivity of a significant number of firms.

Table 1 (page 60) provides insight into the relationship between firm size and business type and the measures of impact for productivity. The type of business does not seem to have a significant relationship or impact on the measures for productivity. Firm size, however, does show a significant impact.

The contingency tables constructed for the size of firm and measures of impact for productivity clearly show that the larger firms (21 or more employees) are impacted more than the smaller firms.

Production Cost Savings

Firm Size	Major Impact	Minor Impact	No Impact
Small	12	6	52
Medium	7	1	21
Large	40	22	60

Tau=.266; sig. level=.01

Manpower Savings

Firm Size	Major Impact	Minor Impact	No Impact
Small	5	2	63
Medium	8	0	13
Large	23	18	81

Tau=.218; sig.level=.0002

Time Saved

Firm Size	Major Impact	Minor Impact	No Impact
Small	26	10	35
Medium	5	1	15
Large	29	16	77

Tau=.156; sig. level=.200

These tables show that the impact on production cost savings and manpower savings was greatest for the large firms. While it was still significant for time saved, there was a strong impact in this category for smaller firms.

These data confirm that the activities of the technology broker had significant impact on the productivity of the firms with which they worked. While the greatest impact was not associated with the small firms, the impact was very important to the medium and larger firms.

Competitive Position

Another of the variables listed in the category of measures of impact on business outcomes is "stronger competitive position". Recorded was a response of "major impact, minor impact, or no impact" to whether the activities of the broker had an impact on the firm's competitive position. The frequency distribution for this variable showed that 49% of the firms said there was major impact, 14% had minor impact, and 37% showed no impact. Sixty-three percent (63%) of the firms said that there was impact. This percentage shows that the brokers had a positive impact on the competitive position of the firms with which they deal.

Table 3 (page 62) shows a very strong relationship between the variables strong competitive position and increased business (tau=.677; sig. level=.000). The contingency table that compares these two variables shows that when there was an activity performed by the broker that had major impact on strengthening the firms competitive position, there was also major impact on its increase in business.

Table 2 (page 61) clearly identifies which activities of the broker have the strongest impact on the firm's competitive position. The most important activity is suggesting alternative approaches to problem solving (tau=.183; sig.level=.001), followed by providing technical information (tau=.039; sig. level=.01), then problem identification (tau=.148; sig. level=.06). There are others with varying degrees of significance, including technology acquisition, and market identification.

This outcome brings some additional clarity to what kinds of activities a broker should provide to the firm in order to help strengthen its competitive position. Significant impact, in any case, is provided by the technology brokering activity relative to the competitive position of the firm.

Technical Capacity

The Virginia technology transfer program is charged with the mission of improving the economic performance of the Commonwealth's small and medium sized companies through the application of technology. Implicit in that charge is to improve the technical capacity of the client firms. The data collected for this research includes information that could provide insight as to whether the brokers are helping to improve the technical capacity of their clients.

The variable "stronger technical capacity" is another of the variables included in the grouping for the measures of impact of business outcomes. The frequency distribution for that outcome shows that 34% of the firms said that the brokers had a major impact, 17% listed the impact as minor, and 49% said there was no impact. When taken together, just over half of the firms said that the brokers had either major or minor impact on the strength of the firm's technical capacity.

Table 2 (page 61) shows which brokering activities were the most important in strengthening the firms technical capacity. Those activities, in order of significance, are suggesting alternative approaches (tau=.214; sig. level=.002), technology acquisition (tau=.201; sig. level=.020), product design (tau=.191; sig. level=.033), and technology modification (tau=.168; sig. level=.019). The data show that the activities of the broker help to strengthen the technical capacity of the firms.

Management

Among the variables for critical brokering activities are a subgrouping that represent measures of business management. These variables include capital formation, assistance in international trade, market identification, meeting government regulations, and workforce development. Given the charge of the technology transfer program in Virginia, it seems appropriate to determine if there is significant effort in, and impact on assisting with business management issues.

The frequency distribution for these variables begins to reveal the answer to this question. The question was asked if the brokers did or did not provide help in these areas. The following list enumerates the percentage of yes responses for each variable:

Market identification	23%
Government regulations	11%
International trade	5%
Capital formation	5%
Financial management	3%

This distribution shows that a minimal amount of effort has been devoted to management issues. The possible exception to that generalization is in the area of "market identification". Much of what the brokers do is provide technical information to their clients. Often this information includes market information about new technology products they are considering adding to their product line. This information is crucial to the successful completion of the technology transfer. If the market information is not provided, then the firm may not take the final step in the process.

The other variable in this grouping that has a higher percentage distribution is "meeting government regulations". While it is not as high as "market identification", it requires explanation. Some of the activities in which the brokers engage is assisting firms meet various regulations of the government: local, state, and federal. These regulations are often related to the environment. Many cases have resulted in the brokers identifying technologies that allow the client firms to meet these regulations.

Table 2 (page 61) reveals the relationship between the critical brokering activities and the measures of impact. Selecting the measure of impact "strong management capacity" and observing which of the brokering activities have significant impact on it, provides insight as to the level of impact the brokers have on management. Only "workforce development" has a significant impact on management (tau=.167; sig. level=.002). Interestingly, the other activities that have a significant impact on "strong management capacity" are product design, suggesting alternative approaches to problems, and providing technical information. These variables are considered to be more related to technical areas.

The data strongly support the fact that the brokers are not engaged in business management activities. When there is a significant impact on "strong management capacity", it is a result of the broker being engaged in a technology related activity.

One final finding that is of note has to do with the use of the Virginia Polytechnic Institute and State University's Newman Library. The Center for Innovative Technology provides support for a small staff at the library that constitutes the Virginia Tech Information Center (VTIC). The function of that staff is to provide data base searching services for the technology brokers at the community colleges. If a broker is working with a client that needs information that can be accessed through a data base, VTIC does the search and supplies the broker with the information. The frequency distribution shows that the brokers used that service 45% of the time. When a contingency table was built to illustrate the number of times the library was used when the broker provided technical information, the results showed that the library service was very important to the effectiveness of the program. In 82 of 98 cases when technical information was provided, the VTIC was used (tau=.403; sig. level=.000). This confirms the importance of the VTIC service.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Conclusions

The most powerful inference that can be gleaned from this study is a clear definition of the market of Virginia firms best served by the technology transfer program. Those firms are characterized by the variables of business type and firm size. The brokers have the highest level of impact when working with semi-technical and technical firms that have 11 or more employees. The data show that the most impact is recorded among larger firms, that is, with 21 or more employees.

The study also revealed emphatically which critical brokering activities had the most impact on business outcomes. The most important activities include providing technical information, suggesting alternative approaches to problems, technology implementation, technology modification, and market identification. When brokers engaged in these activities, they had significant impact on increasing business, retaining business, improving productivity, and strengthening the firms' competitive position and technical capacity.

Finally, the study revealed that the brokers in the technology transfer program did not work, to any significant degree, with firms on management issues. When a firm reported that the broker assisted it in attaining a stronger management capacity, it was generally as a result of the broker providing technology related assistance. Even when these results were reported, they did not occur with any significant frequency.

Implications

While the client group that the author anticipated to be impacted most by the brokers' activities was different than the theoretical work suggested, much of the theory about the diffusion of innovation was supported in this study. The significance of homophily and heterophily as they relate to the diffusion of innovation are supported by this research. The largest group served by the Virginia technology transfer program are semi-technical firms. They have some similarities to the possessors of technology, but are also quite different in many of their perspectives. Rogers, in his book Inducing Technological Change for Economic Growth and Development, suggests that brokers are more important in situations of heterophilous communication. That is certainly the situation, even among semi-technical firms. The data in this study clearly support the important role that the broker plays in the technology transfer process and it is consistent with the theoretical base for the study.

The model for the research utilization process that Rogers suggests is also supported in this study. The role that the brokers play in the Virginia program is consistent with the relationships shown in the model. These are the relationships among the client system, change agent system, and research system. The change agent system serves to translate information between the other two systems and keeps the process moving. That is exactly the role of the brokers in the Virginia program.

The role of the broker is NOT to be an expert in all fields. It simply is to know how and where to access the expertise that is required by the client firm. The successful performance of this role implies the development of and access to a dynamic network of resources and expertise. The data in this study show that the most frequent activity in which the broker engages is "providing technical information". In order to accomplish this task, the broker must access a large network, which, in practice, is precisely what is done. This is completely consistent with the network theory suggested earlier in this study. In theory, and in practice, the broker is the central pivot point in the network.

The implications of the findings of this study are significant. They provide a framework in which to develop and operate a technology transfer program that will be successful. The parameters of such a program should include a clear definition of who should be served, and how they should be served. This study answers those questions.

The data indicate that when brokers focus on the activities of providing technical information, suggesting alternative approaches to solving problems, and providing assistance with technology implementation, acquisition, and modification, to the appropriate firms, they can expect a high level of success. The appropriate firms that should be targeted by the brokers are technical or semi-technical in nature, with 11 or more employees. When brokers engage in the appropriate activities with the appropriate firms, the expected results include significant positive impact on the firms' productivity and technical capacity. This leads to those firms being in a stronger competitive position. When operated within the appropriate parameters, a technology transfer program has significant impact on the economic performance of its client firms.

APPENDIX A

Topics for Further Study

1. Analysis of activity by geographic region of Virginia:
The data can be analyzed by geographic region of the state. Virginia has very distinct regions within its borders. A possible breakdown would be southwest, central, north, and southeast. Each of these regions has its own set of demographic, social, and economic characteristics that could have an impact on the success of a technology transfer program.

2. Comparative study of Virginia's technology transfer program to others in the U.S.:
Technology transfer programs are become more frequent among the states. They are increasingly perceived as good ways to enhance the economic base of an area. Understanding how other jurisdictions approach the issue of implementing a program would not only be helpful to Virginia, but a comparative analysis would benefit the nation.

3. Analysis of marketing hours to number of cases generated:
The data contains the number of hours spent by the broker marketing the program to potential users. An analysis of how much time spent to generate a client would be helpful in establishing baseline marketing information.

4. Analysis of the relationship of the technology transfer program to the community colleges:
The partnership between the colleges and CIT has beneficial to each of the partners. There could, however, be additional ways to enhance the benefit derived by each. Such a study could include an organizational analysis to find ways to track what the broker has done for the college, and vice versa.

APPENDIX B

CONFIDENTIAL

DIRECTOR'S CASE RECORD

Director:______________________ CASE # (C.C. CODE)__________________

Client:____

Address:____

City/Town:____Zip:___________

Telephone:(_____)_____________ Legislative District:________________

PART A: BACKGROUND DATA

1. Primary contact (name):____

Title:____

Department:____

Telephone:_______________________________

2. Number of employees at facility:________________

3. Years this operation has been underway:__________

4. SIC Code for Primary Function (4 digit):_________

5. Principal business activity (brief description):

____

____

____

PART B: MARKETING/CLIENT CONTACTS (Complete after marketing phase)

6. Date of contact:________________________

7. Main person contacted (if different from #1):

Name:______________________________Position:__________________

8. Outcome of marketing (Check):

____ Request for assistance

____ No services to be delivered (why not):______________________________

____

____

9. Director's time for marketing phase (hours):__________________________

PART C: PROJECT DEFINITION (Complete when client and director have defined the problems to be addressed).

10. Project description:____

____

____

11. Date when project defined:__________________________________

12. Client estimate of economic value of proposed services for 1 year from implementation (if feasible to estimate): $______________

13. Client estimate of economic value of proposed services for 3 years from implementation (if feasible to estimate): $______________

14. Annual dollar volume of sales, services, deliveries, etc. from this facility: $______________

PART D: PROJECT CLOSURE (Complete when program services are terminated or completed)

15. Date of closure:______________

16-A Why was the project closed:

____"Technology services delivered" ____"Closed for other reasons"

16-B (If "Closed for other reasons") what were they:

____ Client resolved the problem without using program resources
____ Turned out to be a "non-problem"
____ Could not solve the problem (explain):______________________

____

____

____

ANSWER FOLLOWING QUESTIONS ONLY FOR "TECHNOLOGY SERVICES DELIVERED" CASES:

17. Services provided: ____

____

____

____

____

18. Director's time for services delivery phase, estimated (hours): ________

19. Which of the following were critically important (i.e., essential) sources of assistance in delivering these services:

____ Director personally providing technical assistance
____ Other directors
____ Host community college
____ Other colleges or universities
____ CIT
____ VPI or other library support services
____ Federal laboratories
____ Private consultants
____ Other (identify): ______________________________

20. Were any out of state sources important in resolving the problem: NO/YES (if yes, which): ______________________________

21. Where did program services provide significant and substantial assistance to the client (check all that apply):

____ Problem identification	____ Suggesting alternative approaches
____ Providing tech info	____ Technology acquisition
____ Tech implementation	____ Technology modification
____ Capital formation	____ Financial management
____ Product design/dev.	____ Market identification, assessment
____ International trade	____ Meeting government regulations
____ Management assistance	____ Work force development

____ Other (explain): ______________________________

22. Client and director estimate (if feasible) of the economic value of ETD services for:

1 year from full implementation: $____________________

3 years from full implementation: $____________________

23. Client and director estimate (if feasible) of the number of jobs saved/ created as a result of ETD services:_____________

24. What are the estimated or projected impacts of the services on the client and how substantial are the impacts likely to be:

	Major Impact	Minor Impact	No Impact	Not Appl.
Increased business volume	____	____	____	____
Retention of existing business	____	____	____	____
Production costs savings	____	____	____	____
Manpower savings	____	____	____	____
Time saved in introducing new products	____	____	____	____
Stronger competitive position	____	____	____	____
Stronger managerial capacity	____	____	____	____
Stronger technical capacity	____	____	____	____
Other with major impact (explain):	____	____	____	____

25. How did this project benefit the community college (check all that apply):

____ Training courses
____ Curriculum development
____ Student Placement
____ Other (explain):________________________________

____ Increased enrollment: how many FTE's:_____________
____ New hardware or software
____ Faculty involvement/development

26. Other relevant and useful comments, qualifications or observations:

APPENDIX C

CODE BOOK
MASTER'S THESIS RESEARCH

STEPHEN S. COOPER

Variables

IDNUM, firm number

INSTID, college number
- 01 = TNCC
- 02 = TCC/PDCC
- 03 = NVCC
- 04 = CVCC
- 05 = VWCC
- 06 = NRCC
- 07 = WCC
- 08 = SVCC
- 09 = DCC
- 10 = PHCC

NBREMPL, number of employees in firm

YRSOP, number of years firm has been in operation

SIC, standard industrial classification of firm

BUSTYPE, type of business
- 1 = technical
- 2 = semi-technical
- 3 = non-technical

MKTHRS, number of hours spent marketing the technology services to the firm

PROJDUR, number of months from project definition to project closure

RSNCLSD, reason project is closed
- 1 = technology services delivered
- 2 = project was a non-problem
- 3 = problem could not be solved

Sources that were critically important to delivery of services (1=yes, 2=no)

DIRTA, director personally provides technical assistance
OTRDIR, other directors

HSTCC, host community college
OTRCOL, other colleges or universities
CIT
LIB, VPI or other library support
FEDLAB, federal laboratories
PVTCON, private consultants

Areas in which broker provided significant and substantial services (1=yes, 2=no)

PRBLMID, problem identification
PRVDTI, providing technical information
TECHIMP, technology implementation
CAPFORM, capital formation
PRODESN, product design/development
INTLTRD, international trade management assistance
ALTAPR, suggesting alternative approaches
TECHACQ, technology acquisition
TECHMOD, technology modification
FINMGT, financial management
MKTID, market identification/assessment
GOVTREG, meeting government regulations
WKFRCDEV, work force development
NMBRCHKS, number of checks

Economic value of broker services to firm (thousands of dollars)

$ 1 year from full implementation
$ 3 years from full implementation
number of jobs saved/created

Type and level of impact of broker services (1=major, 2=minor, 3=no impact, 4=not applicable)

INCRSBUS, increased business volume
RTNBUS, retention of existing business
PRODCST, production cost savings
MNPR, manpower savings
TMSVD, time saved in introducting new product
STRGCOMP, stronger competitive position
STRGMGMT, stronger managerial capacity
STRGTEC, stronger technical capacity

Value of the project to the host community college (1=yes, 2=no)

TRNG, training courses (non-credit)
CD, curriculum development
SP, student placement
CRS, courses (credit)
HDWSFW, new hardware or software made available to college
FCLTDEV, faculty development/involvement

NMBRCHKD, total number checked
FTES, number of full time equivalent students
generated for host community college as a
result of broker contact

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Table 1.

Chi Square Probability Level & Kendall's Tau
for Firm Size, Business Type, and Measures of Impact

Measures of Impact

	Incr Bus	Rtn Bus	PrdCst Svng	Mnpr Svng	Time Svd	StgCmp Pstn	Stgmgt Cpcty	StgTec Cpcty
Firm Size	.204	* .196	* .266	*** .218	.156	.149	** .026	.134
Business Type	.116	.024	.050	.015	.024	.082	** .141	.164

Blank cell: p> .050
*: p = .050
**: p = .010-.040
***: p = .001-.009

Table 2.

Chi Square Probability Level & Kendall's Tau for Critical Brokering Activities and Measures of Impact

Measures of Impact

Critical Brokering Activities	Incr Bus	Rtn Bus	PrdCst Svng	Mnpr Svng	Time Svd	StgCmp Pstn	Stgmgt Cpcty	StgTec Cpcty
Prblmid	.033	*** .217	.081	-.025	.069	.148	-.143	.018
Prvdti	.155	.037	.146	.059	.146	** .039	.127	.183
Techimp	.029	.058	*** .263	*** .166	.044	.083	.080	.098
Capform	.011	.006	.028	.009	.001	.006	** .070	.012
Prodesn	** .158	.039	.156	.004	** .187	.098	** .124	** .191
Intltrd	** .099	.009	.003	.015	* .074	.054	.023	.042
Altapr	*** .054	*** .211	*** .390	*** .210	*** .028	*** .183	*** .241	*** .214
Techacq	.034	.007	*** .228	-.128	.018	.106	.026	** .201
Techmod	.001	.061	*** .224	.093	.092	.026	.023	** .168
Finmgt	.027	.048	.000	.008	.001	.009	** .075	.021
Mktid	*** .324	.098	.141	*** .144	.169	.135	.099	.071
Govtreg	.065	.038	.053	.005	.060	.012	.059	.024
Wkfrcdev	.036	.051	** .076	** .127	.019	.034	*** .167	** .058

Blank cell: p> .050
*: p = .050
**: p = .010-.040
***: p = .001-.009

Table 3.

Chi Square Probability Level & Kendall's Tau
for Measures of Impact

Measures of Impact

Measures of Impact	Incr Bus	Rtn Bus	PrdCst Svng	Mnpr Svng	Time Svd	StgCmp Pstn	Stgmgt Cpcty	StgTec Cpcty
Incrbus		*** .415	** .124	.083	*** .287	*** .677	.128	.160
Rtnbus	*** .416		*** .408	*** .253	*** .003	*** .657	*** .214	*** .163
PrdCst Svng				*** .472	.116	*** .347	*** .256	*** .203
MnprSvng					.031	*** .227	*** .318	.020
TimeSvd						*** .258	.018	*** .168
StgCmp Cpcty							*** .236	*** .342
StgMgt Cpcty								.035
StgTec Cpcty								

Blank cell: p> .050
*: p = .050
**: p = .010-.040
***: p = .001-.009

VITA

Stephen S. Cooper, born on December 31, 1946, in Dayton, Ohio, is the Director of Economic and Technology Development at Thomas Nelson Community College. His position is the result of a partnership between Virginia's Center for Innovative Technology (CIT) and the Virginia Community College System. Cooper has been in his current position since August of 1987. He is responsible for working with small to medium sized businesses in helping them utilize technology, and thus making them more profitable.

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